Early Journal Content on JSTOR, Free to Anyone in the World

This article is one of nearly 500,000 scholarly works digitized and made freely available to everyone in the world by JSTOR.

Known as the Early Journal Content, this set of works include research articles, news, letters, and other writings published in more than 200 of the oldest leading academic journals. The works date from the mid-seventeenth to the early twentieth centuries.

We encourage people to read and share the Early Journal Content openly and to tell others that this resource exists. People may post this content online or redistribute in any way for non-commercial purposes.

Read more about Early Journal Content at http://about.jstor.org/participate-jstor/individuals/early-journal-content.

JSTOR is a digital library of academic journals, books, and primary source objects. JSTOR helps people discover, use, and build upon a wide range of content through a powerful research and teaching platform, and preserves this content for future generations. JSTOR is part of ITHAKA, a not-for-profit organization that also includes Ithaka S+R and Portico. For more information about JSTOR, please contact support@jstor.org.

CONCERNING AERIAL PHOTOGRAPHIC MAPPING: A REVIEW *

By James W. Bagley

To the geographer, to the explorer, and to the pioneer interested in learning the character and resources of remote parts of the world the possibility of mapping before penetrating is like the short way to India and Cathay.

Mapping of Inaccessible Country

The application of this possibility in Morocco, where the French have the task of establishing order in a large area of country which is inhospitable both because of its character and the unfriendliness of the tribes, is discussed by Colonel Noirel. The method here employed for mapping is to establish points of control on the terrain occupied and to mark them with signals which can be identified on aerial photographs. Flying at great height directly over the marked points, two series of photographs are taken, one with a camera pointed downward and a second with a camera pointed obliquely toward the mountains. Though Colonel Noirel does not so state, it is supposed that the two cameras are joined rigidly together and that the relationship between the two chambers is carefully determined. The effect of this arrangement would be that the aerial positions and orientations of the photographs could be obtained from the "vertical" [1] photographs which embrace the targets, and afterwards directions and vertical angles taken from the oblique photographs would supply data to map the mountains. Topographic reconnaissance maps of the scale 1: 200,000 which were made in this fashion of country south of Taza have been used.

The method used by the French is undoubtedly feasible for mapping a narrow belt of absolutely inaccessible country of high mountains, but it is doubtful whether it will permit of extension over large areas of considerable

---

* H. Noirel: La topographie moderne et les applications de la photographie aux levés topographiques. Maps, diagrs., ills. *Bull. Bimestriel de la Soc. de Topographie de France*, Vol. 45, 1921, pp. 106–127. Paris.

C. G. Lewis and H. G. Salmond: Experiments in Aeroplane Photo Surveying. 53 pp.; diagrs. *Survey of India Professional Paper No. 19.* Dehra Dun, 1920. 3 s. 11 x 8½ inches.

M. N. Macleod, comp.: Mapping from Air Photographs. 66 pp.; maps, diagrs., ills., index. General Staff. War Office, London, 1920. 4 s. 13 x 8½ inches.

H. Roussilhe: Applications de la photographie aérienne aux levés topographiques de précision. Diagrs. *Annales Hydrogr.*, No. 703, Ser. 3, Vol. 1, 1917, pp. 81–176. Paris.

—— Rapport sur les études techniques effectuées in 1919 et 1920 sous la direction de M. H. Roussilhe. Reconstitution Foncière et Cadastre, Ministère des Régions Libérées, Paris, 1921.

—— The Use of Aerial Photographs in Topographic Mapping. 31 pp.; maps, diagrs., ills. *Air Service Information Circular No. 184*, Washington, D. C., 1921.

[1] During the World War it became customary in the armies of the United States and Britain to speak of aerial photographs which had been taken with the optical axis of the camera directed downward as "verticals." The French usually keep in mind the position of the negative in the camera and call them horizontal photographs.

depths such as the topographer maps at comparatively small scale on a reconnaissance trip of three months with pack train in much of our western mountainous country. Locations thus made of points in the reaches adjacent to the marked control points might be accurate enough to serve as control for another similar set of photographs, but it is improbable that locations made from a second or third set of photographs would afford sufficiently reliable control to continue by such an overlapping process the mapping of a deep zone.

Colonel Noirel also speaks of the attractive work which the topographer has in northern Africa where he interests himself in Roman archeology as found in buried cities, in botany, the relation of flora to soil, entomology, geology, etc. His picture is alluring.

Use in Hydrographic Charting

During the last year the Service Géographique has prepared planimetric maps in France at the scale 1: 10,000 from aerial photographs but will add the contours by ground work. Progress has also been made in hydrographic charting by the use of aerial photography in conjunction with a procedure of making locations by sounds. When out of sight of the shore, positions of rocks or other obstructions to navigation have been accurately determined by the time required for the detonation of a bomb exploded under water to travel to three or more shore stations where equipment for registering the disturbance is emplaced. It is stated that the British have located the positions of vessels sunk at the Battle of Jutland as distant as 200 miles from a shore station by this method. When there is only one station on shore available, radio-direction apparatus has been employed in combination with bombs, the intervals of time required for the disturbance to travel by air and by water being used to determine distances. Rocks at depths as great as 40 meters have been photographed in calm clear water.

Experiments in Aerial Surveying in India

Major Lewis and Captain Salmond have given a faithful record in their "Experiments in Aeroplane Photo Surveying" carried out at Agra in India. The object of the experiments was to determine whether plane maps of two different classes, one at a scale of a mile to the inch, the other at a very large scale of a city, could be made by means of aerial photographs as cheaply and as satisfactorily as by the current ground methods.

The report is divided into two parts; the first by Major Lewis, the second by Captain Salmond. Major Lewis is rather emphatic in stating that "It would appear then that there is nothing to be gained by adopting the air method for normal one inch surveys in the plains of India." Captain Salmond concurs with a statement to the same effect. Concerning large-scale city surveys, definite conclusion is not reached as to the value of the method tried; but the suggestion is made that further experimentation should be carried out.

An estimate, based on the experiment, of the cost of further inch-to-mile surveys by aerial photography gives a rate nearly twice that for surveys made during the three years 1914–1917 by the ground method. The average cost by the ground method is given as 9.1 rupees (about three dollars) per square mile. This is a low cost for plane surveys at the inch-to-mile scale. The explanation seems to be that the amount of data to be obtained for the map is small, the country is easy to travel through, and the native personnel can be employed at modest wages. From the standpoint of economics the test was a severe one for aerial photographic surveying. The conclusion reached may be the final one for work in India, but there was much room for improvement in the instruments used and the manner of carrying out the work.

An area of about five hundred square miles near Agra was selected for the small-scale survey. It consisted of two adjacent fifteen-minute quadrangles in plains country. The air force employed was four airplanes with customary personnel. These were loaned for the experiment with the understanding that they could be kept but a few days and might be recalled at any time. The holding in leash of the air contingent apparently led to an undue hurrying of the photographic work with consequent confusion and an ultimate prolongation of the time required to secure the photographs, and in the end the area had not been completely covered.

The photographic equipment was of an old type such as has for a long time in this country been considered obsolete. It appears that they lacked accessory aircraft instruments to fly courses and to regulate exposure intervals. Captain Salmond, who discusses at some length the aircraft equipment used as compared with that desired, states "that for future work of this kind, *either* machines, instruments, ground control, etc., must be so improved as to eliminate the personal factor in pilots and observers, and so obtain uniform results of a high standard of perfection *or* all pilots and observers employed must have specialized in this class of work, which differs very considerably from active service work." Automatic cameras are now in use, and means have been provided to regulate them; but the getting of useful photographs still depends on a skillful pilot and a trained observer. There seems to be no way to escape the necessity of giving competent men adequate training if success is to be reached in making maps from aerial photographs. In the Information Circular put out by the U. S. Army Air Service considered below, two examples of employing aerial photographs to prepare plane maps at the scale 1:62,500 are given. Each of these maps comprised the area of a fifteen-minute quadrangle. In both instances the work was successful from all standpoints.

A Treatise on Aerial Mapping

In "Mapping from Air Photographs" Colonel Macleod has prepared a valuable treatise. It is evident that he has drawn freely upon the information and experience which he gained while in France during the war. Making allowances for new data which have been gathered from experimentation since the date of the publication, the field of the subject has been fairly well covered.

Colonel Macleod gives consideration to many methods or schemes for making use of aerial photographs in mapping rather than confining his endeavor to the presentation of a particular method. Methods of correction for distortion arising from tilt of the camera, such as were employed extensively by the several armies during the World War, receive a chapter of more than twenty pages. This includes an elaborate discussion of the use and mechanism of types of the camera lucida. Part II, which takes up about half of the quarto, consists of "Proofs of Geometrical and Other Theorems Relating to the Plotting and Rectification of Air Photos." Some general principles of perspective figures and special applications of the principles to instruments are given.

In a chapter headed "The Framework" it is made plain that an elaborate net of control points is considered indispensable for accurate mapping with aerial photographs. It is assumed that the control points must be established wholly by ground work. Mapping at what in the United States are considered large scales is in mind. In the United States and in all new countries the great need is for maps at moderate scales (one inch to the mile up to three inches to the mile), and control has to be established as the maps are made. It is therefore of great importance, when considering means and methods of operation, whether the cost of a large number of control points has to be borne or whether it is possible to get along with a fewer number. The feasibility of applying aerial photographs to surveys depends to a large extent on the amount of supplementary ground work required to make them useful. A method of aerial photography cannot be successful for our moderate-scale surveys unless it can be applied with comparatively few points of control which can be readily and inexpensively established.

PHOTO RESTITUTION

In contrast to Colonel Macleod's compilation, H. Roussilhe has given a study of a particular method of using aerial photographs in connection with accurate mapping. His primary purpose was to discuss the principles of photo restitution[2] as applied to apparatus he devised. As Director of a division (Reconstitution Foncière et Cadastre) of the Ministère des Régions Libérées, he is concerned with restoring properties in the devastated parts of France to their owners, and in order to make the surveys needed to do this expeditiously he turned to aerial photography as a possible aid. The nature of this task required that the results be accurate enough for surveys of the cadastral class. He worked to make his apparatus and method meet that standard. At the date of publication the opportunity had not been afforded him to verify the accuracy of results by a field demonstration, but it is understood that triangulation had been started to make a test survey at the scale 1 : 2,000.

---

[2] The word "restitution" has been employed by the French in connection with aerial photographs for ten years or more. It was adopted by the English-speaking forces during the World War and, as used by them, is equivalent to plotting data from aerial photographs. As employed by the French it means the treatment of a photograph through all of the steps necessary to produce a plan or a map of the objects it pictures.

A large part of the study is given to a discussion of the principles and general conditions of photographic restitution, the characteristics and description of photo-restitution apparatus, and the method of employing the apparatus which was devised by himself. Relationships to be maintained between factors of the aerial camera and those of the restitution apparatus to simplify and facilitate the mapping work are established, and graphs and tables are supplied to provide for ranges in altitudes of flights and inclinations of the camera.

A chapter is devoted to the method to be followed for making surveys with aerial photographs, and, taking 1:2,000 as the scale to be employed, details of the several phases of the work are sketched. The permissible error for positions of triangulation stations is stated as but two-tenths of a meter. Points of the great triangulation net in France of the first order of accuracy are accepted as meeting this requirement, but points of the second and third order do not as a rule meet the requirement and therefore can be used only with caution. At least three points of control are required for each photograph. Levels must also be established with an accuracy commensurate with that desired for the positions of control points. It is considered sufficient to have the elevations of only the control points, for it is expected that all other required vertical data can be obtained from the photographs. It is proposed to take both vertical and oblique photographs in series such that there shall be four photographs covering every part of the terrain. Any point to be located can therefore be intersected by a line from each of at least three photographs. The oblique photographs will be taken with the optical axis of the camera inclined about 30° from the vertical. The elevation chosen for flights is 2,000 meters above the terrain. The cameras being equipped with 50-centimeter lenses, the approximate scale of the photographs will be 1 : 4,000. It is intended to select enough negatives from the lot thus obtained to make two sets of restitutions, and one set is to be employed to check the results of the other set.

The need for a high order of accuracy in the control scheme is emphasized. This presages a high order of accuracy in making locations of random points and in determining their elevations. Estimates of the refinement possible in the results are given in a chapter headed "Accuracy of Results." Here it is stated that if negatives of the approximate scale of 1 : 4,000 are used to construct a map of the scale of 1 : 2,000, the relief of the terrain covered by any negative being not more than plus or minus 40 meters (with reference to control points), errors of location made will not exceed two-tenths of a meter, and errors of elevations determined will not exceed half a meter. Cadastral surveys will require exceedingly careful work, but topographic mapping at scales commonly used does not require so high a degree of refinement in results. For work at the scale 1 : 10,000 it is stated that all except mountainous country could be satisfactorily surveyed by the method.

Major Roussilhe very properly refers to Colonel Laussedat [3] as the father of photogrammetry and gives credit to Captain (later Lieut.-Colonel) Saconney [4] for his studies made of photographs taken with kites before 1913.

AERIAL PHOTOGRAPHY FOR CADASTRAL AND GEOGRAPHICAL SURVEYS

Since the preceding paragraph was written there has been received a report on the employment of aerial photography for cadastral surveys and for geographic surveys. This report is an amplification of the matter treated in the 1917 annals with several important modifications and additions that are the results of further experience. It is to a certain extent a supplement to the earlier work. The two should be studied together.

The report consists of 116 quarto pages in four parts and is well illustrated with more than fifty figures drawn at liberal scales. The first part is devoted to a description of instruments and the results of a trial survey made to test the method. The second part deals with the procedure of the method, concrete evidence being presented in fair manual form. Details of the method as applicable to mapping at ordinary (1 : 5,000 to 1 : 20,000) scales are explained in the third part. In the fourth part is seen the influence of the trial survey. Here are mentioned the modifications that are to be made in the aerial camera to be used for cadastral surveys.

The survey was made to compare the aerial method with the ordinary ground method of conducting cadastral surveys. The map was drafted at the scale 1 : 1,000, and, in spite of the difficulties encountered, the results are stated to have been more accurate (accidental errors are entirely eliminated) than those obtained by the ground method. The rate of progress was also greater by the aerial method than by the ground method. Elevations could not be determined from the negatives so accurately as by levels run on the ground. The cost of the aerial method did not compare with that by the ground method so favorably as did accuracy of locations and speed. The experience gained by the test led to a significant decision, namely, that aerial photographs intended for survey use ought to be taken by three joined cameras, so arranged that one chamber should point down, one obliquely sidewise, and one obliquely backward or forward. Photographs so taken with multiple cameras can be more readily employed, will give greater accuracy in results, and will cost less to obtain. This is an exceedingly interesting conclusion, for it corroborates conclusions which have been reached in this country after the making of studies and comprehensive tests.

---

[3] Aimé Laussedat: Recherches sur les instruments, les méthodes et le dessin topographiques, Gauthier Villars, Paris, Part I, 1901, Part II, 1903.

[4] J. T. Saconney: Métrophotographie, O. Doin et Fils, Paris. 1913.

Work of the U. S. Government Bureaus

The report of the Committee of the Board of Surveys and Maps published as an Information Circular by the Air Service is a résumé of work done by several bureaus of the Federal Government in connection with the use of aerial photography in mapping. The purpose of the report was to determine as clearly as possible how successfully aerial photographs could be used in topographic mapping and in surveys of coasts and what promise lay in future development. The report contains accounts of work done by the Navy, the Army, the U. S. Geological Survey, and the Coast and Geodetic Survey. Several examples of the practical application of aerial photographs are given. Among these are a revision of a coast chart to show changes of a shore line caused by storm action at Tucker Beach, N. J.; a revision of the Santa Monica quadrangle, California, showing great growth of the city of Los Angeles, Santa Monica, and near-by towns, during a period of twenty-five years; the preparation of field sheets of the Schoolcraft quadrangle, Michigan, to which contours are to be added by ordinary methods on the ground; and a plane map, based on land lines, of a quadrangle in Oklahoma which shows cultural development, drainage, and woodland areas. Specimens of mosaics and types of aerial photographs are also shown.

A section of the report is given to a description of aerial mapping cameras and the methods of their use. Problems connected with the application of aerial photography to map-making are treated under the headings: "Pilot's Duties," "Observer's Duties," and "Results of Tests at McCook Field, April-July, 1920."

The cost of making maps from aerial photographs is a difficult question to deal with. This is not the only branch of surveying which suffers from that distinction. All classes of surveys are hampered in many quarters of the globe by unfavorable weather. Weather is of extreme importance in obtaining aerial photographs. On the other hand it is possible with certain types of American aircraft cameras to photograph a thousand square miles in a single fair day with but one camera. Records of weather with regard for aerial photographic possibilities and costs of operating aircraft will undoubtedly after a time become available, so that satisfactory estimates of the cost of all phases of mapping with aerial photographs may be made. This time is to a certain extent anticipated by the report, and numerous items of cost incurred in getting aerial photographs are given.

Part II is a statement showing the possibilities of aerial photography in mapping, with the types of cameras available. Here is reproduced a small map of the United States which shows by shading those parts where relief is too great for aerial photographs to be successfully employed. About four-fifths of the country is represented as susceptible from the technical standpoint of being mapped by the use of aerial photographs.

The average vertical aerial photograph, which is but slightly inclined to the horizontal plane, may be used to measure angles from its center, because lines drawn from the center to objects pictured represent fairly accurately the true bearings to the objects. So used the photograph is exactly the equivalent of a map which is mounted on a slightly tilted plane-table. By means of the three-point or of the tracing-paper method a fair location can be made of the point occupied with the plane-table, even though the plane-table be only approximately level. Having made the location of the station, the map can be satisfactorily oriented and any object in view can be sighted. The same sort of tracing-paper solution can be made to determine the position of the center of vertical aerial photographs, with reference to three or more known points that it embraces, by placing over the photograph a tracing of the known points and shifting it about until the points fall on their respective radial lines. When this is done, the tracing is properly oriented with respect to the photograph, and bearings to any object pictured can be traced. The centers of the photographs always correspond to the positions to be occupied.

This is the key to the use of vertical aerial photographs for mapping. It affords a means of extending surveys over considerable distances providing there is a base to start from and a point at the end to tie to. It is not uncommon, in reconnaissance and exploratory surveys, to extend maps by the plane-table intersection method for a hundred miles or more from a single comparatively short base. Extensions of maps by aerial photographs have been successfully made over distances as great as twenty miles; and, though the proof that similar extensions can be made over distances as great as a hundred miles is lacking, the evidence available indicates that there is only one thing that can hinder its being satisfactorily done, and that is excessive relief. For reconnaissance surveys the amount of relief which can be successfully coped with is roughly about 1,000 feet between two overlapping photographs, and this corresponds to about 1,000 feet in any mile of the course. A continuous rising and falling of the ground, if the slope be not greater than 1 in 5, would be no more difficult to map by aerial photography than the average rolling country.

The problem of determining elevations from aerial photographs to suffice for placing contours on maps is a complex one. With instruments and facilities now available the solution necessarily involves, and must be preceded by, the accurate location of points of control. To be practicable in moderate-scale surveys of large areas, this means that the necessary points of control must come in large part from the photographs themselves. This task is receiving the attention of mapping agencies of the Federal Government.